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(71) Applicant: Matsushita Electric Industrial Co., Ltd.  
1006, Oaza Kadoma  
Kadoma-shi Osaka-fu, 571 (JP)

(72) Inventor: Watanabe, Koji  
Kourigaoka Gaaden Haitzu 504§12-4  
Kourigaoka 9-chome Hirakata-shi Osaka (JP)

Hayashi, Katsuhiko Mingle AP Akane Ichibankan 2B  
3-32, Kikawa Nishi 4-chome  
Yodogawa-ku Osaka-shi Osaka (JP)

Minakuchi, Nobuaki  
35-1110, 5-ban Kasuga 1-chome  
Sulta-shi Osaka (JP)

Misaki, Masayuki  
76, Nishinokyo Shokushi-cho Nakagyo-ku  
Kyoto (JP)

Teral, Kenichi  
3-1306, 1-ban, Shigino Nishi 2-chome Joto-ku  
Osaka-shi Osaka (JP)

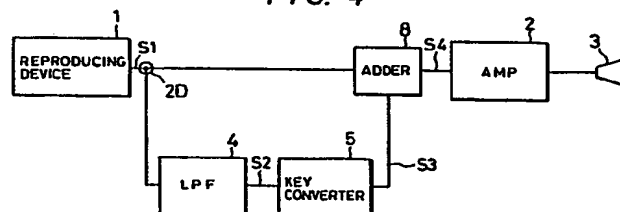
Nakama, Yasutoshi  
1658-499, Kita Tahara-cho  
Ikoma-shi Nara-ken (JP)

(74) Representative: Senior, Alan Murray et al  
J.A. KEMP & CO 14 South Square Gray's Inn  
London WC1R 5EU (GB)

(54) Low-pitched sound creator.

(57) An analog sound signal is outputted. Low-frequency components are selected from the outputted analog sound signal so that a low-pitched sound signal is derived from the analog sound signal. A key of the low-pitched sound signal is lowered so that a very-low-pitched sound signal is derived from the low-pitched sound signal. The analog sound signal and the very-low-pitched sound signal may be converted into corresponding sounds respectively.

FIG. 4



EP 0 240 286 A2

## Description

### LOW-PITCHED SOUND CREATOR

#### BACKGROUND OF THE INVENTION

This invention relates to a low-pitched sound creator which can improve an aural sensation in low-pitched sound reproduced by an audio system, an audio-visual system, or the like. This invention also relates to a method of creating a low-pitched sound.

Some sound reproducing devices have a head deriving and reproducing a sound signal from sound data stored in a magnetic memory such as a magnetic tape. Reproducing heads have characteristics causing low-pitched sound cut-off frequencies. Specifically, these heads fail to acceptably reproduce original sound signals in frequency ranges below such cut-off frequencies.

Advanced sound reproducing systems have an additional function of compensating for poor low-pitched sound reproducing characteristics of heads.

#### SUMMARY OF THE INVENTION

It is an object of this invention to provide a low-pitched sound creator or a sound signal processing device which can improve an aural sensation in low-pitched sound reproduced by an audio system, an audio-visual system, or the like.

It is another object of this invention to provide a method which allows an excellent aural sensation in low-pitched sound.

In a low-pitched sound creator according to a first aspect of this invention, an analog sound signal is outputted. Low-frequency components are selected from the outputted analog sound signal so that a low-pitched sound signal is derived from the analog sound signal. A key of the low-pitched sound signal is lowered so that a very-low-pitched sound signal is derived from the low-pitched sound signal. The analog sound signal and the very-low-pitched sound signal may be converted into corresponding sounds respectively.

In a low-pitched sound creator according to a second aspect of this invention, two channel sound signals are outputted. A subtraction between the two channel signals is derived and thereby a subtraction signal indicative thereof is generated. The two channel signals are added to form a mixed signal. A first low-pass filter selects low-frequency components from the subtraction signal and thereby generates a first low-pitched sound signal representing the selected low-frequency components of the subtraction signal. A second low-pass filter selects low-frequency components from the mixed signal and thereby generates a second low-pitched sound signal representing the selected low-frequency components of the mixed signal. A key of the first low-pitched sound signal is lowered so that a very-low-pitched sound signal is derived from the first low-pitched sound signal. An envelope of the second low-pitched sound signal is detected. The very-low-pitched sound signal is selectively passed and cut off in accordance with the detected

envelope.

In a low-pitched sound creator according to a third aspect of this invention, an analog sound signal is outputted. First and second low-pass filters having different cut-off frequencies derive first and second low-pitched sound signals from the analog sound signal respectively. Arbitrary one of the first and second low-pitched sound signals is selected. A key of the selected low-pitched sound signal is halved so that a key-halved signal is derived from the selected low-pitched sound signal.

In a low-pitched sound creator according to a fourth aspect of this invention, two channel sound signals are outputted. A subtraction between the two channel signals is derived and thereby a subtraction signal indicative thereof is generated. The two channel signals are added to form a mixed signal. A device detects whether or not the two channel signals contain voice components. Arbitrary one of the subtraction signal and the mixed signal is selected in accordance with whether or not the two channel signals contain voice components, and a selected signal representing the selected one of the subtraction signal and the mixed signal is generated. A low-pass filter selects low-frequency components from the selected signal and thereby generates a low-pitched sound signal representing the selected low-frequency components. A key of the low-pitched sound signal is halved so that a very-low-pitched sound signal is derived from the low-pitched sound signal.

In a method of creating a low-pitched sound according to a fifth aspect of this invention, low-frequency components are selected from a sound signal. A key of the selected low-frequency components is lowered. The key-lowered components are converted into a corresponding sound.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a conventional audio system.

Fig. 2 is a graph showing frequency characteristics of the reproducing device of Fig. 1.

Fig. 3 is a block diagram of another conventional audio system.

Fig. 4 is a block diagram of an audio system including a low-pitched sound creator according to a first embodiment of this invention.

Fig. 5 is a graph showing frequency characteristics of the reproducing device and the audio system of Fig. 4.

Fig. 6 is a block diagram of an internal structure of the key converter of Fig. 4.

Fig. 7 is a diagram of an essential portion of the internal structure of the key converter of Figs. 4 and 6.

Fig. 8 is a block diagram of an audio system including a low-pitched sound creator according to a second embodiment of this invention.

Fig. 9 is a block diagram of an audio system including a low-pitched sound creator accord-

ing to a third embodiment of this invention.

Fig. 10 is a block diagram of an audio system including a low-pitched sound creator according to a fourth embodiment of this invention.

Fig. 11 is a block diagram of an audio system including a low-pitched sound creator according to a fifth embodiment of this invention.

Fig. 12 is a block diagram of an audio system including a low-pitched sound creator according to a sixth embodiment of this invention.

Fig. 13 is a block diagram of an internal structure of the level determination circuit of Fig. 12.

Fig. 14 is a block diagram of an audio system including a low-pitched sound creator according to a seventh embodiment of this invention.

Fig. 15 is a block diagram of an audio system including a low-pitched sound creator according to an eighth embodiment of this invention.

Fig. 16 is a block diagram of an audio system including a low-pitched sound creator according to a ninth embodiment of this invention.

Fig. 17 is a block diagram of an audio system including a low-pitched sound creator according to a tenth embodiment of this invention.

Fig. 18 is a block diagram of an audio system including a low-pitched sound creator according to an eleventh embodiment of this invention.

Fig. 19 is a block diagram of an internal structure of the detector of Fig. 18.

Like and corresponding elements are usually denoted by the same reference characters throughout the drawings.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before embodiments of this invention will be explained, conventional audio systems will be described briefly for a better understanding of this invention.

Fig. 1 shows a conventional audio system having a reproducing device 81 such as a tape deck or a radio receiver. An output signal S1 from the reproducing device 81 is magnified by an amplifier 82 and is then converted by a loudspeaker 83 into a corresponding sound M.

The tape deck 81 has a head deriving and reproducing a sound signal S1 from sound data stored in a magnetic tape or the like. Fig. 2 shows frequency characteristics of the tape deck 81 which depend mainly on frequency characteristics of the reproducing head. In Fig. 2, the voltage level of the sound signal S1 varies as a function of the frequency of the sound signal S1 along the line L1. At frequencies above a low-pitched sound cut-off frequency f1, the tape deck 81 has essentially flat frequency characteristics. As the frequency decreases from the cut-off value f1, the level of the sound signal S1 drops. The hatched area A1 denotes an unproduced range having frequencies below the cut-off frequency f1.

As is understood from Fig. 2, the conventional audio system of Fig. 1 can not acceptably reproduce sounds having frequencies lower than the cut-off frequency f1.

Fig. 3 shows another conventional audio system also having a reproducing device 81. An output signal S1 from the reproducing device 81 is applied via a branching device 88 to an amplifier 82 and a low-pass filter (LPF) 84. After the sound signal S1 is amplified by the device 82, it is converted into a corresponding sound by a loudspeaker 83. The low-pass filter 84 derives a low-pitched sound signal S2 from the sound signal S1. For example, the low-pitched sound signal S2 have frequencies equal to or below 150 Hz. After the low-pitched sound signal S2 is magnified by an amplifier 86, it is converted into a corresponding sound by a loudspeaker 87.

The conventional audio system of Fig. 3 can compensate for poor low-pitched sound reproducing characteristics of the reproducing device 81 to some extents. If an original sound signal fails to have low-frequency components, sounds reproduced by the audio system of Fig. 3 will not have corresponding low-pitched components.

Fig. 4 shows an audio system including a low-pitched sound creator according to a first embodiment of this invention. As shown in Fig. 4, the audio system has a reproducing device 1 such as a tape deck or a radio receiver. An output terminal of the reproducing device 1 is connected to an input terminal of a branching device 2D. A first output terminal of the branching device 2D is connected to a first input terminal of an adder 8. A second output terminal of the branching device 2D is connected to an input terminal of a low-pass filter (LPF) 4. An output signal S1 from the reproducing device 1 is applied via the branching device 2D to the first input terminal of the adder 8 and to the input terminal of the low-pass filter 4.

The low-pass filter 4 selects low-frequency components from the sound signal S1 and thereby derives a low-pitched sound signal S2 from the signal S1. A cut-off frequency of the low-pass filter 4 is preferably around 150 Hz. An output terminal of the low-pass filter 4 is connected to an input terminal of a key or pitch converter 5 so that the output signal S2 from the low-pass filter 4 is applied to the key converter 5. The key converter 5 serves as a frequency lowering converter. Thus, the key converter 5 lowers the frequencies or pitches of the signal S2 outputted by the low-pass filter 4. Preferably, this device 5 converts the low-pitched sound signal S2 into a second low-pitched sound signal S3 having frequencies half the respective frequencies of the corresponding sound signal S2. In other words, the low-frequency components of the sound signal S1 selected by the low-pass filter 4 are lowered in frequency by a value corresponding to an octave. In this way, a very-low-pitched sound signal S3 is derived from the low-pitched sound signal S2.

It should be noted that the key converter 5 may decrease the frequencies of the low-pitched sound signal S2 by other factors. For example, the frequencies of the very-low-pitched sound signal S3 may be one-third or one-fourth of the respective frequencies of the low-pitched sound signal S2.

An output terminal of the key converter 5 is connected to a second input terminal of the adder 8

so that the very-low-pitched sound signal S3 is applied to the second input terminal of the adder 8. The sound signal S1 and the very-low-pitched sound signal S3 are added by the device 8 to form a processed or modified sound signal S4. An output terminal of the adder 8 is connected to an input terminal of an amplifier 2 so that the modified sound signal S4 is applied to the amplifier 2. An output terminal of the amplifier 2 is connected to a loudspeaker 3. After the modified sound signal S4 is amplified by the device 2, it is converted into a corresponding sound by the loudspeaker 3.

Fig. 5 shows frequency characteristics of the reproducing device 1 and frequency characteristics of the audio system of Fig. 4. In Fig. 5, the broken line N1 denotes low frequency characteristics of the reproducing device 1, while the solid line N2 denotes low frequency characteristics of the audio system of Fig. 4. The hatched area L2 between the lines N1 and N2 denotes an added low-frequency reproduced range created by the sound signal processing through the key converter 5. A low cut-off frequency f2 in the frequency characteristics of the audio system of Fig. 4 is lower than a low cut-off frequency f1 in the frequency characteristics of the reproducing device 1 by a value corresponding to an octave. The added low-frequency reproduced range L2 improves an aural sensation in respect of low-pitched sounds. Furthermore, even in cases where sound signals lack very-low-frequency components, e.g., even in the case of an AM radio broadcasting sound signal or a movie sound signal, the sound signal processing through the key converter 5 creates very-low-frequency components from a base sound signal and adds them to the base sound signal to form a modified sound signal rich in low-frequency components, so that an excellent aural sensation is allowed in respect of low-pitched sounds.

Fig. 6 is a block diagram of an internal structure of the key converter 5. As shown in Fig. 6, the key converter 5 has an input terminal I01 subjected to a low-pitch sound signal S2 outputted by the low-pass filter 4 (see Fig. 4). An analog-to-digital (A/D) converter I02 derives a one-bit digital signal D0 from the input analog signal S2 through adaptive delta modulation. This adaptive delta modulation uses a syllable compander which depends on whether or not four successive one-bit digital signals are in the same state. A dynamic random-access memory I04 holds the digital signal D0. A first digital-to-analog (D/A) converter I05 derives an analog signal S6 from a one-bit digital signal D1 outputted by the memory I04. A second digital-to-analog (D/A) converter I18 derives an analog signal S7 from a one-bit digital signal D1 outputted by the memory I04. An adder I16 derives a very-low-pitched sound signal S3 from the analog signals S6 and S7 outputted by the D/A converters I05 and I18. Specifically, the analog signals S6 and S7 from the D/A converters I05 and I18 are added by the device I16 to form a very-low-pitched sound signal S3. The very-low-pitched sound signal S3 is transmitted to an output terminal I06 of the key converter 5.

A generator I08 outputs clock pulses D2 at a fixed frequency. A generator I10 derives conversion clock

pulses f0 from the fixed-frequency clocks D2. The conversion clocks f0 are applied to the A/D converter I02. The A/D converter I02 samples and converts the low-pitched sound signal S2 at timings determined by the conversion clocks f0.

Operation of the digital memory I04 is controlled in accordance with various signals including a row address strobe (RAS) signal, a column address strobe (CAS) signal, a write enable (WE) signal, a write address signal, and a read address signal.

A write address counter I12 derives a signal D4 from the fixed-frequency clocks D2. This signal D4 represents a write address. The write address signal D4 is applied to the memory I04. The current incoming digital signal D0 is transmitted to and held by a segment of the memory I04 corresponding to the address represented by the write address signal D4.

A generator I09 outputs clock pulses D7 at a variable frequency. A generator I11 derives a memory control signal D3 from the fixed-frequency clocks D2 and the variable-frequency clocks D7. The memory control signal D3 is applied to the memory I04. Specifically, the memory control signal D3 includes the RAS signal, the CAS signal, and the WE signal.

A generator I13 derives write address counter load signals D5 and D9 from the fixed-frequency clocks D2. A first read address counter I14 derives a signal D6 from the write address signal D4, the read address counter load signal D5, and the variable-frequency clocks D7. This signal D6 represents a first read address. The first read address signal D6 is applied to the memory I04. Data is read out from a segment of the memory I04 corresponding to the first read address represented by the signal D6. A second read address counter I20 derives a signal D8 from the write address signal D4, the read address counter load signal D9, and the variable-frequency clocks D7. This signal D8 represents a second read address. The second read address signal D8 is applied to the memory I04. Data is read out from a segment of the memory I04 corresponding to the second read address represented by the signal D8. The first read address signal D6 and the second read address signal D8 are generally designed to occur alternately at regular intervals.

A generator I15 derives conversion clock pulses fv from the variable-frequency clocks D2. The conversion clocks fv are applied to the D/A converters I05 and I18. The D/A converters I05 and I18 sample and convert the memory output digital signal D1 at timings determined by the conversion clocks fv.

Data writing to the memory I04 is performed periodically at a frequency determined by the fixed-frequency clocks D2. Data reading from the memory I04 is performed periodically at a frequency determined by the variable-frequency clocks Fv. The ratio between the pitches of the key-converter input and output signals S2 and S3 is generally proportional to the ratio between the frequencies of the data writing and reading.

A counter I40 derives an amplitude operation signal from the variable-frequency clocks D7. The amplitude operation signal is applied to an operation device I41. The operation device I41 derives first and

second multi-bit digital signals from the amplitude operation signal. The first multi-bit signal from the operation device I41 is applied to a first data selector I43. The second multi-bit signal from the operation device I41 is applied to a second data selector I49. The fixed-frequency clocks D2 are applied to the data selectors I43 and I49. The first data selector I43 sequentially selects one bit data of the first multi-bit signal from the calculation device I41 in accordance with the fixed-frequency clocks D2. The second data selector I49 sequentially selects one bit data of the second multi-bit signal from the calculation device I41 in accordance with the fixed-frequency clocks D2.

The output signal from the first data selector I43 is applied to a first input terminal of an AND gate I44. The first D/A converter I05 includes a circuit deriving or detecting a syllable compander digital signal. This compander signal generated in the first D/A converter I05 is applied to a second input terminal of the AND gate I44. A signal outputted by the AND gate I44 is applied to the first D/A converter I05. The first D/A converter I05 also includes a circuit adjustably controlling or limiting the amplitude of the output signal S6. The signal fed to the first D/A converter I05 from the AND gate I44 adjusts the limiting circuit so that the amplitude of the signal S6 is controlled in accordance with the signal from the AND gate I44.

The output signal from the second data selector I49 is applied to a first input terminal of an AND gate I50. The second D/A converter I18 includes a circuit deriving or detecting a syllable compander digital signal. This compander signal generated in the second D/A converter I18 is applied to a second input terminal of the AND gate I50. A signal outputted by the AND gate I50 is applied to the second D/A converter I18. The second D/A converter I18 also includes a circuit adjustably controlling or limiting the amplitude of the output signal S7. The signal fed to the second D/A converter I18 from the AND gate I50 adjusts the limiting circuit so that the amplitude of the signal S7 is controlled in accordance with the signal from the AND gate I50.

The amplitude controls of the signals S6 and S7 are designed to remove or prevent noises caused by discontinuities in waveforms occurring during sound pitch changing process. In general, such noises occur at known regular timings. In view of this fact, the combination of the devices I40, I41, I43, I44, I49, and I50 performs the amplitude controls of the signals S6 and S7 in time-dependent manner.

The output signal S6 from the first D/A converter I05 is periodically enabled and nullified. The output signal S7 from the second D/A converter I18 is periodically enabled and nullified. Approximately, the signal S6 is enabled but the signal S7 is nullified during a first period, and the signal S6 is nullified but the signal S7 is enabled during a subsequent second period. Near the boundary between the first and second periods, the amplitudes of the signals S6 and S7 are controlled in a cross fade-in/fade-out manner. Specifically, near the boundary between the first and second periods, one of the signals S6 and S7 is gradually enabled while the other is gradually nullified. These controls of the signals S6 and S7 are realized through the amplitude controls by the

combination of the devices I40, I41, I43, I44, I49, and I50.

Fig. 7 is a diagram of an essential portion of the key converter of Fig. 6. As shown in Fig. 7, an output signal DI from the memory I04 (see Fig. 6) is applied to a data input terminal of a shift register I24 via a connection point I23. A latch clock signal fv derived from the variable-frequency clocks D7 is applied to a control terminal of the shift register I24 via a connection point 22. The shift register I24 has a set of four positive or non-inverting output terminals Q1-Q4 generating four signals DI4-DI7 respectively and a set of four negative or inverting output terminals  $\bar{Q}1$ - $\bar{Q}4$  generating four signals DI8-DI21 respectively. The output signals DI4-DI21 shift with respect to the output terminals at timings determined by the latch clock signal fv.

The output signals DI4-DI7 from the shift register I24 are applied to four input terminals of a NAND gate I25 respectively. The other output signals DI8-DI21 from the shift register I24 are applied to four input terminals of a NAND gate I26 respectively. An output signal D22 from the NAND gate I25 is applied to a first input terminal of a NAND gate I27. An output signal D23 from the NAND gate I26 is applied to a second input terminal of the NAND gate I27. An output signal D24 from the NAND gate I27 assumes a high or "1" level state only when all of the signals DI4-DI7 simultaneously assume the same state. Accordingly, only in the case where four or more successive signals DI outputted from the memory I04 (see Fig. 6) are in the same state, the output signal D24 from the NAND gate I27 assumes a high or "1" level state. In this way, a syllable compander signal D24 is derived which is used to control adaptive operation. The adaptive control signal D24 is applied to the second input terminal of the AND gate I44.

The output signal DI4 from the shift register I24 is applied to a data input terminal of a custom IC (for example, "M5225L" made by Mitsubishi Electric Corporation) I28 forming a digital-to-analog converter. The second pin of the IC I28 is grounded by a fixed resistor I29 and a capacitor I34. A constant voltage is applied to the junction between the resistor I29 and the capacitor I34 via a fixed resistor I35. The collector of a transistor I31 is connected via a fixed resistor I30 to the junction between the resistor I29 and the capacitor I34. The emitter of the transistor I31 is grounded. The base of the transistor I31 is grounded via a fixed resistor I33. An output signal D30 from the AND gate I44 is applied to the base of the transistor I31 via a fixed resistor I32. A parallel combination of a fixed resistor I36 and a capacitor I37 is connected between the sixth pin and the seventh pin of the IC I28. The seventh pin of the IC I28 outputs a signal S6 which is applied via a connection point I38 to the adder I16 (see Fig. 6).

The D/A converter I05 (see Fig. 6) includes the shift register I24, the NAND gates I25-I27, the IC I28, the transistor I31, the resistors I29, I30, I32, I33, I35, and I36, and the capacitors I34 and I37. The output digital signal DI from the memory I04 (see Fig. 6) is converted into a corresponding analog signal S6 which is outputted via the connection point I38.

The variable-frequency clocks D7 are applied to the amplitude operation counter I40 via a connection point I39. The counter I40 derives an amplitude operation signal D26 from the variable-frequency clocks D7. The amplitude operation signal D26 is applied to the operation device I41. The operation device I41 derives a multi-bit digital signal D27 from the amplitude operation signal D26. The multi-bit signal D27 from the operation device I41 is applied to the first data selector I43. The fixed-frequency clocks D2 are applied to the first data selector I43 via a connection point I42. The device I43 sequentially selects one bit of the multi-bit digital signal D27 in accordance with the fixed-frequency clocks D2. The first data selector I43 outputs a signal D29 reflecting the selected data. The signal D29 is applied to the first input terminal of the AND gate I44.

While the adaptive operation control signal D24 remains in a high or "1" level state, the AND gate I44 is opened so that a high or "1" level pulse signal D29 from the first data selector I43 is allowed to move to the base of the transistor I31 as an output signal D30 from the AND gate I44. When the high level signal D30 is applied to the base of the transistor I31, the transistor I31 is made conductive, discharging the capacitor I34 and decreasing the voltage at the junction between the capacitor I34 and the resistor I29. A drop in the voltage at the junction between the capacitor I34 and the resistor I29 generally causes a decrease in the voltage of the analog signal S6. In this way, the amplitude of the output analog signal S6 is controlled in accordance with the signals D24 and D29. Specifically, the duration of the high or "1" level pulse D29 determines the amplitude of the output analog signal S6. The combination of the devices I40, I41, and I43 varies the duration of the high or "1" level pulse D29 in time-dependent manner so as to perform desired fade-in/fade-out control of the amplitude of the output analog signal S6.

The operation device I41 also generates a second multi-bit digital signal in accordance with the amplitude operation signal D26. The second multi-bit signal is applied to the second data selector I49 (see Fig. 6). The second multi-bit signal is generally similar to the multi-bit signal applied to the first data selector I43.

The combination of the second D/A converter I18 (see Fig. 6), the second data selector I49 (see Fig. 6), and the AND gate I50 (see Fig. 6) is similar to the combination of the first D/A converter I05, the first data selector I43, and the AND gate I44 except for the following point. The second data selector I49 sequentially selects one bit of the multi-bit signal from the operation device I41 in a reverse or opposite order with respect to the data selection order in the first data selector I43. Accordingly, the output analog signal S7 undergoes amplitude fade-in/fade-out control opposite that of the other output analog signal S6.

It should be noted that the key converter 5 of Figs. 6 and 7 is one example, although it is not prior art. The key converter 5 may also be of any known types.

Fig. 8 shows a second embodiment of this invention which is similar to the embodiment of

Figs. 4-7 except for the design changes indicated below.

The adder 8 (see Fig. 4) is omitted from this embodiment. The branching device 2D is directly coupled to the amplifier 2 so that the sound signal SI from the reproducing device 1 is applied to the input terminal of the amplifier 2. Accordingly, the sound signal SI is converted into a corresponding sound by the loudspeaker 3.

The output terminal of the key converter 5 is connected to an input terminal of an amplifier 6 so that the very-low-pitched sound signal S3 is applied to the amplifier 6. An output terminal of the amplifier 6 is connected to a loudspeaker 7, such as a woofer. After the very-low-pitched sound signal S3 is amplified by the device 6, it is converted by the loudspeaker 7 into a corresponding sound.

Fig. 9 shows a third embodiment of this invention. As shown in Fig. 9, in this embodiment, a reproducing device 1a outputs a first channel signal SL and a second channel signal SR. A first channel output terminal of the reproducing device 1a is connected to an input terminal of a first branching device 1L so that the first channel signal SL is applied to the first branching device 1L. A second channel output terminal of the reproducing device 1a is connected to an input terminal of a second branching device 1R so that the second channel signal SR is applied to the second branching device 1R.

A first output terminal of the first branching device 1L is connected to an input terminal of an amplifier 2L. A second output terminal of the first branching device 1L is connected to a first input terminal of an operation or calculation circuit 10. The first channel signal SL from the reproducing device 1a is applied to the amplifier 2L and the operation circuit 10 via the first branching device 1L.

An output terminal of the amplifier 2L is connected to a loudspeaker 3L. After the branched first channel signal SL is amplified by the device 2L, it is converted by the loudspeaker 3L into a corresponding sound.

A first output terminal of the second branching device 1R is connected to an input terminal of an amplifier 2R. A second output terminal of the second branching device 1R is connected to a second input terminal of the operation circuit 10. The second channel signal SR from the reproducing device 1a is applied to the amplifier 2R and the operation circuit 10 via the second branching device 1R.

An output terminal of the amplifier 2R is connected to a loudspeaker 3R. After the branched second channel signal SR is amplified by the device 2R, it is converted by the loudspeaker 3R into a corresponding sound.

The operation circuit 10 includes a subtractor or difference calculator which outputs a signal S8 corresponding to a difference between the first channel signal SL and the second channel signal SR. The operation circuit 10 may include additional devices which adjust phases and levels of the two signals SL and SR so as to minimize the level of the output signal S8.

An output terminal of the operation circuit 10 is connected to an input terminal of a low-pass filter (LPF) 4 so that the signal S8 is applied to the

low-pass filter 4. The low-pass filter 4 selects low-frequency components from the signal S8 and thereby derives a low-pitched signal S9 from the signal S8. A cut-off frequency of the low-pass filter 4 is preferably around 150 Hz.

An output terminal of the low-pass filter 4 is connected to an input terminal of a key or pitch converter 5 so that the output signal S9 from the low-pass filter 4 is applied to the key converter 5. The key converter 5 serves as a frequency lowering converter. Preferably, this device 5 converts the low-pitched signal S9 into a second low-pitched signal S10 having frequencies half the respective frequencies of the corresponding signal S9. In other words, the low-frequency components of the signal S8 selected by the low-pass filter 4 are lowered in frequency by a value corresponding to an octave. In this way, a very-low-pitched signal S10 is derived from the low-pitched signal S9.

It should be noted that the key converter 5 may decrease the frequencies of the low-pitched signal S9 by other factors. For example, the frequencies of the very-low-pitched signal S10 may be one-third or one-fourth of the respective frequencies of the low-pitched signal S9.

The key converter 5 is preferably similar to that of Figs. 6 and 7. The key converter 5 may also be of known types.

An output terminal of the key converter 5 is connected to an input terminal of an amplifier 6 so that the very-low-pitched signal S10 is applied to the amplifier 6. An output terminal of the amplifier 6 is connected to a loudspeaker 3W such as a woofer or a super woofer. After the very-low-pitched signal S10 is amplified by the device 6, it is converted by the loudspeaker 3W into a corresponding sound.

It was experimentally found that if a sound signal having vocal or voice components was subjected to key down process, the resulting signal and the corresponding reproduced sound tended to be distorted. In general, the two channel signals SL and SR contain vocal or voice components at essentially the same level and the same phase. In view of these facts, subtraction between the two channel signals SL and SR is performed by the operation circuit I0 to derive a signal S8 essentially free from vocal or voice components. After this signal S8 is treated by the low-pass filter 4, it is subjected to key down process in the pitch converter 5. In this way, a signal essentially free from vocal components is subjected to key down process, so that the resulting signal and the corresponding reproduced sound less tend to be distorted.

Fig. 10 shows a fourth embodiment of this invention which is similar to the embodiment of Fig. 9 except for the following design changes.

As shown in Fig. 10, the output terminal of the low-pass filter 4 is connected to an input terminal of a branching device I2D. A first output terminal of the branching device I2D is connected to a first input terminal of an adder 9. A second output terminal of the branching device I2D is connected to the input terminal of the key converter 5. The output signal S9 from the low-pass filter 4 is applied to the first input terminal of the adder 9 and the key converter 5 via

the branching device I2D. The output terminal of the key converter 5 is connected to a second input terminal of the adder 9 so that the output signal S10 from the key converter 5 is applied to the second input terminal of the adder 9.

In this way, one branched signal S9 bypasses the key converter 5, while the other branched signal S9 is subjected to key down process in the pitch converter 5. The key converter 5 derives the very-low-pitched signal S10 from the inputted branched signal S9. The very-low-pitched signal S10 and the branched signal S9 are added by the device 9 to form a signal S11.

An output terminal of the adder 9 is connected to the input terminal of the amplifier 6 so that the output signal S11 from the adder 9 is applied to the amplifier 6. After the signal S11 is amplified by the device 6, it is converted by the loudspeaker 3W into a corresponding sound.

Fig. 11 shows a fifth embodiment of this invention which is similar to the embodiment of Fig. 9 except for the following design changes.

As shown in Fig. 11, a branching device I2L is interposed between the branching device I1L and the first input terminal of the operation circuit I0. Specifically, an input terminal of the branching device I2L is connected to the branching device I1L so that the first channel signal SL is applied to the input terminal of the branching device I2L. A first output terminal of the branching device I2L is connected to the first input terminal of the operation circuit I0. A second output terminal of the branching device I2L is connected to a first input terminal of an adder 9F. The first channel signal SL is applied via the branching device I2L to the operation circuit I0 and the adder 9F.

Another branching device I2R is interposed between the branching device I1R and the second input terminal of the operation circuit I0. Specifically, an input terminal of the branching device I2R is connected to the branching device I1R so that the second channel signal SR is applied to the input terminal of the branching device I2R. A first output terminal of the branching device I2R is connected to the second input terminal of the operation circuit I0. A second output terminal of the branching device I2R is connected to a second input terminal of the adder 9F. The second channel signal SR is applied via the branching device I2R to the operation circuit I0 and the adder 9F.

The first channel signal SL and the second channel signal SR are added by the device 9F to form a signal S12. An output terminal of the adder 9F is connected to an input terminal of a low-pass filter (LPF) I3 so that the signal S12 is applied to the low-pass filter I3. The low-pass filter I3 selects low-frequency components from the signal S12 and thereby derives a low-pitched signal S13 from the signal S12.

An output terminal of the low-pass filter I3 is connected to a first input terminal of an adder 9B so that the low-pitched signal S13 from the low-pass filter I3 is applied to the first input terminal of the adder 9B. The adder 9B is interposed between the key converter 5 and the amplifier 6. The output

terminal of the key converter 5 is connected to a second input terminal of the adder 9B so that the very-low-pitched signal SI0 is applied to the second input terminal of the adder 9B. The low-pitched signal SI3 and the very-low-pitched signal SI0 are added by the device 9B to form a signal SII.

An output terminal of the adder 9B is connected to the input terminal of the amplifier 6 so that the signal SII is applied to the amplifier 6. After the signal SII is amplified by the device 6, it is converted by the loudspeaker 3W into a corresponding sound.

Fig. 12 shows a sixth embodiment of this invention which is similar to the embodiment of Fig. 11 except for the following design changes. In the embodiment of Fig. 12, a branching arrangement 3D represents the combination of the branching devices 1L, 1R, 12L, and 12R (see Fig. 11).

The adder 9B (see Fig. 11) is omitted from the embodiment of Fig. 12. A switching circuit II and a level determination circuit I4 are added to the embodiment of Fig. 12.

As shown in Fig. 12, the switching circuit II is connected between the output terminal of the key converter 5 and the input terminal of the amplifier 6. When the switching circuit II is closed, the very-low-pitched signal SI0 from the key converter 5 is allowed to travel to the input terminal of the amplifier 6. When the switching circuit II is opened, the application of the very-low-pitched signal SI0 to the amplifier 6 is interrupted. The switching circuit II has a control terminal. The switching circuit II is closed and opened in accordance with a potential at its control terminal.

The output terminal of the low-pass filter I3 is connected to an input terminal of the level determination circuit I4 so that the output signal SI3 from the low-pass filter I3 is applied to the level determination circuit I4. The level determination circuit I4 generates a binary signal SI4 which depends on the amplitude of the input signal SI3. Specifically, the signal SI4 moves between a first level state and a second level state in accordance with whether or not the amplitude of the signal SI3 exceeds a reference level. An output terminal of the level determination circuit I4 is connected to the control terminal of the switching circuit II so that the signal SI4 from the level determination circuit I4 is applied to the control terminal of the switching circuit II.

When the amplitude of the signal SI3 exceeds the reference level, the signal SI4 assumes a first level state, opening the switching circuit II and thereby interrupting the application of the very-low-pitched signal SI0 to the amplifier 6. Accordingly, in this case, the very-low-pitched signal SI0 is not converted into a sound.

When the amplitude of the signal SI3 is equal to or lower than the reference level, the signal SI4 assumes a second level, closing the switching circuit II and thereby applying the very-low-pitched signal SI0 to the amplifier 6. Accordingly, in this case, the very-low-pitched signal SI0 is converted into a corresponding sound by the loudspeaker 3W.

A cut-off frequency of the low-pass filter I3 is lower than the cut-off frequency of the low-pass filter 4. The cut-off frequency of the filter I3 is generally

higher than half the cut-off frequency of the filter 4. In the case where the filters 4 and I3 have sharp frequency characteristics, the cut-off frequency of the filter I3 is preferably half the cut-off frequency of the filter 4.

The combination of the adder 9F, the low-pass filter I3, and the level determination circuit I4 essentially serves to determine whether or not at least one of the two channel signals SL and SR originally contains appreciable amounts of very-low-pitched sound components. When at least one of the two channel signals SL and SR originally contains appreciable amounts of very-low-pitched sound components, the switching circuit II is opened by the signal SI4 from the level determination circuit I4 so that the very-low-pitched signal SI0 derived through key down process is prevented from changing to a sound.

If at least one of the two channel signals SL and SR originally contained appreciable amounts of very-low-pitched sound components and the pitch-converted signal SI0 containing created very-low-pitched sound components was changed to a sound, the original very-low-pitched sound components and the created very-low-pitched sound components would interfere with each other and thereby unacceptable distortions would occur. In this embodiment, such unacceptable distortions are prevented, since the conversion of the very-low-pitched signal SI0 to a corresponding sound is interrupted when at least one of the two channel signals SL and SR originally contains appreciable amounts of very-low-pitched sound components.

Fig. 13 shows an internal design of the level determination circuit I4. As shown in Fig. 13, the level determination circuit I4 includes an input terminal I4A subjected to the signal SI3 from the low-pass filter I3. The input terminal I4A is connected to an input terminal of an envelope detector or integrator I5 so that the signal SI3 is applied to the device I5. The integrator I5 generates a signal SI5 which depends on the amplitude of the input signal SI3. Specifically, the signal SI5 reflects an envelope of the signal SI3. Accordingly, the level of the signal SI5 corresponds to the amplitude of the signal SI3. An output terminal of the integrator I5 is connected to a first input terminal of a comparator I6 so that the envelope signal SI5 is applied to the first input terminal of the comparator I6. A level setting circuit I7 outputs a reference level signal SI6. An output terminal of the level setting circuit I7 is connected to a second input terminal of the comparator I6 so that the reference level signal SI6 is applied to the second input terminal of the comparator I6. The comparator I6 generates a binary signal SI4 in accordance with the input signals SI5 and SI6. Specifically, when the level of the envelope signal SI5 exceeds a reference level represented by the signal SI6, the signal SI4 assumes a first level state. When the level of the envelope signal SI5 is equal to or lower than the reference level, the signal SI4 assumes a second level state. An output terminal of the comparator I6 is connected to a connection point I4B leading to the control terminal of the switching circuit II (see Fig. 12). Accordingly, the output signal SI4 from the



comparator 16 is transmitted to the switching circuit 11 via the connection point 14B.

Fig. 14 shows a seventh embodiment of this invention which is similar to the embodiment of Figs. 12 and 13 except for the following design changes.

As shown in Fig. 14, the output terminal of the low-pass filter 4 is connected to an input terminal of a branching device 12D. A first output terminal of the branching device 12D is connected to the input terminal of the key converter 5. A second output terminal of the branching device 12D is connected to a first input terminal of an adder 18. The output signal S9 from the low-pass filter 4 is applied via the branching device 12D to the key converter 5 and the first input terminal of the adder 18.

The output terminal of the key converter 5 is connected to a second input terminal of the adder 18 so that the very-low-pitched signal S10 from the key converter 5 is applied to the second input terminal of the adder 18. The low-pitched signal S9 from the low-pass filter 4 and the very-low-pitched signal S10 from the key converter 5 are added by the device 18 to form a signal S17. An output terminal of the adder 18 is connected to the input terminal of the switching circuit 11 so that the signal S17 is applied to the switching circuit 11. The switching circuit 11 enables and interrupts the application of the signal S17 to the amplifier 6 in accordance with the signal S14.

Fig. 15 shows an eighth embodiment of this invention which is similar to the embodiments of Figs. 12 and 13 except for the following design changes.

As shown in Fig. 15, the output terminal of the adder 9F is connected to an input terminal of a branching device 12F. A first output terminal of the branching device 12F is connected to the input terminal of the low-pass filter 13. A second output terminal of the branching device 12F is connected to an input terminal of a low-pass filter (LPF) 19. The output signal S12 from the adder 9F is applied via the branching device 12F to the low-pass filters 13 and 19. The low-pass filter 19 selects low-frequency components from the signal S12 and thereby a low-pitched signal S19 from the signal S12.

The output terminal of the switching circuit 11 is connected to a first input terminal of an adder 20 so that an output signal S18 from the switching circuit 11 is applied to the first input terminal of the adder 20. An output terminal of the low-pass filter 19 is connected to a second input terminal of the adder 20 so that an output signal from the low-pass filter 19 is applied to the second input terminal of the adder 20. The signals S18 and S19 are added by the device 20 to form a signal S20. An output terminal of the adder 20 is connected to the input terminal of the amplifier 6 so that the signal S20 from the adder 20 is applied to the amplifier 6.

Fig. 16 shows an audio system including a low-pitched sound creator according to a ninth embodiment of this invention. As shown in Fig. 16, the audio system has a reproducing device 1 such as a tape deck. The reproducing device 1 has a control terminal subjected to a binary control signal D. The reproducing device 1 assumes either of a normal speed state and a double speed state in accordance

with the control signal D. The reproducing speed in the double speed state is twice the reproducing speed in the normal speed state.

The output terminal of the reproducing device 1 is connected to an input terminal of a branching device 30D so that the output signal S1 from the reproducing device 1 is applied to the branching device 30D. A first output terminal of the branching device 30D is connected to an input terminal of a low-pass filter (LPF) 22. A second output terminal of the branching device 30D is connected to an input terminal of a low-pass filter (LPF) 23. A third output terminal of the branching device 30D is connected to a first input terminal 29A of a switching circuit 29. The output sound signal S1 from the reproducing device 1 is applied via the branching device 30D to the low-pass filters 22 and 23, and the first input terminal 29A of the switching circuit 29.

The low-pass filter 22 selects low-frequency or low-pitched sound components from the sound signal S1 and thereby derives a low-pitched sound signal S21 from the signal S1. An output terminal of the low-pass filter 22 is connected to a first input terminal 24A of a switching circuit 24 so that the low-pitched sound signal S21 is applied to the first input terminal 24A of the switching circuit 24.

The low-pass filter 23 has a cut-off frequency higher than a cut-off frequency of the low-pass filter 22. The low-pass filter 23 selects audible-frequency or audio components from the sound signal S1 and thereby derives an audio signal S22 from the signal S1. An output terminal of the low-pass filter 23 is connected to a second input terminal 24B of the switching circuit 24 so that the audio signal S22 is applied to the second input terminal 24B of the switching circuit 24.

An output terminal 24C of the switching circuit 24 is connected to an input terminal of a key or pitch converter 5 so that an output signal S23 from the switching circuit 24 is applied to the key converter 5. The switching circuit 24 has a control terminal subjected to the binary control signal D. The switching circuit 24 passes either of the low-pitched signal S21 and the audio signal S22 to the key converter 5 in accordance with the control signal D.

The key converter 5 serves as a frequency lowering converter. In other words, the key converter 5 lowers the frequencies or pitches of the signal S23 outputted by the switching circuit 24 and selected from either of the low-pitched sound signal S21 and the audio signal S22. Specifically, this device 5 converts the signal S23 into a signal S24 having frequencies half the respective frequencies of the corresponding sound signal S23. In other words, the signal S23 is lowered in frequency by a value corresponding to an octave. In this way, a frequency-halved sound signal S24 is derived from the signal S23 outputted by the switching circuit 24.

The key converter 5 is preferably similar to that of Figs. 6 and 7. The key converter 5 may also be of known types.

The switching circuit 29 has a control terminal subjected to the binary control signal D. The switching circuit 29 selectively passes and cuts off the sound signal S1 in accordance with the control

signal D.

An output terminal 29C of the switching circuit 29 is connected to a first input terminal of an adder 26 so that an output signal S25 from the switching circuit 29 is applied to the first input terminal of the adder 26. An output terminal of the key converter 5 is connected to a second input terminal of the adder 26 so that the frequency-halved signal S24 is applied to the second input terminal of the adder 26. The signal S25 from the switching circuit 29 and the signal S24 from the key converter 5 are added by the device 26 to form a signal S26.

An output terminal of the adder 26 is connected to an input terminal of an amplifier 2 so that the signal S26 from the adder 26 is applied to the amplifier 2. An output terminal of the amplifier 2 is connected to a loudspeaker 3. After the signal S26 is amplified by the device 2, it is converted by the loudspeaker 3 into a corresponding sound.

When the binary control signal D is at a first level, the reproducing device 1 is in its normal speed state and the switching circuit 24 selects the low-pitched sound signal S21 and passes it to the key converter 5. Accordingly, a very-low-pitched sound signal S24 is created from the low-pitched sound signal S21 by the key converter 5. The very-low-pitched signal S24 is applied to the adder 26. At the same time, the switching circuit 29 passes the sound signal S1 to the adder 26. The very-low-pitched signal S24 and the sound signal S1 are added by the device 26 to form the resulting signal S26, which is amplified by the device 2 and is converted by the loudspeaker 3 into a corresponding sound. In this way, when the binary control signal D is at the first level, the reproducing device 1 operates at a normal speed and created very-low-pitched components are added to the reproduced sound.

When the binary control signal D is at a second level, the reproducing device 1 is in its double speed state and the switching circuit 24 selects the audio signal S22 and passes it to the key converter 5. Accordingly, a frequency-halved sound signal S24 is created from the audio signal S22 by the key converter 5. The frequency-halved signal S24 is applied to the adder 26. At the same time, the switching circuit 29 cuts off the transmission of the sound signal S1 to the adder 26. Accordingly, the output signal S26 contains only the frequency-halved signal S24, which is amplified by the device 2 and is converted by the loudspeaker 3 into a corresponding sound. In this way, when the binary control signal D is at the second level, the reproducing device 1 operates at a speed twice the normal speed and the audio signal S22 equal to an audible portion of the reproducing device output signal S1 is halved in frequency and is then converted into a corresponding sound so that the resulting reproduced sound has the same frequencies as those of an original sound.

Fig. 17 shows a tenth embodiment of this invention which is similar to the embodiment of Fig. 16 except for the following design changes.

As shown in Fig. 17, the adder 26 (see Fig. 16) is omitted from this embodiment. The output terminal 29C of the switching circuit 29 is connected to the

input terminal of the amplifier 2. The output terminal of the key converter 5 is connected to a second input terminal 29B of the switching circuit 29 so that the output signal S24 from the key converter 5 is applied to the second input terminal 29B of the switching circuit 29. The switching circuit 29 passes either of the signals S1 and S24 to the amplifier 2 in accordance with the control signal D.

The output terminal of the key converter 5 is also connected to an input terminal of an amplifier 2W so that the output signal S24 from the key converter 5 is applied to the amplifier 2W. An output terminal of the amplifier 2W is connected to a loudspeaker 3W such as a woofer. The output signal S24 from the key converter 5 is amplified by the device 2W and is then converted by the loudspeaker 3W into a corresponding sound.

When the control signal D is at the first level, the switching circuit 29 passes the sound signal S1 to the amplifier 2 so that the sound signal S1 is converted by the loudspeaker 3 into a corresponding sound. At the same time, the key converter output signal S24 derived from the low-pitched sound signal S21 is converted by the loudspeaker 3W into a corresponding sound.

When the control signal D is at the second level, the switching circuit 29 passes the key converter output signal S24 to the amplifier 2 so that the signal S24 is converted by the loudspeaker 3 into a corresponding sound. At the same time, the key converter output signal S24 is also converted by the loudspeaker 3W into a corresponding sound.

Fig. 18 shows an eleventh embodiment of this invention which is similar to the embodiment of Fig. 9 except for the following design changes.

In the embodiment of Fig. 18, the branching devices 1L and 1R (see Fig. 9) are included in a branching arrangement 4D. The first channel signal SL outputted by the reproducing device 1 is applied to the amplifier 2L via the branching arrangement 4D. The second channel signal SR outputted by the reproducing device 1 is applied to the amplifier 2R via the branching arrangement 4D.

The first channel signal SL is also applied via the branching arrangement 4D to a first input terminal of an adder 10A, a first input terminal of a subtractor 10B, and a first input terminal of a detector 10C. The second channel signal SR is also applied via the branching arrangement 4D to a second input terminal of the adder 10A, a second input terminal of the subtractor 10B, and a second input terminal of the detector 10C.

The device 10A adds the two channel signals SL and SR to form a signal S31. The device 10B derives a difference or subtraction between the two channel signals SL and SR to form a signal S32. The device 10C detects whether or not the signals SL and SR contain vocal or voice components. The detector 10C outputs a binary signal S33 which moves between two level states in accordance with whether or not the signals SL and SR contain vocal or voice components.

An output terminal of the adder 10A is connected to a first input terminal of a switching circuit 10D so that the output signal S31 from the adder 10A is

applied to the first input terminal of the switching circuit 10D. An output terminal of the subtractor 10B is connected to a second input terminal of the switching circuit 10D so that the output signal S32 from the subtractor 10B is applied to the second input terminal of the switching circuit 10D. An output terminal of the detector 10C is connected to a control terminal of the switching circuit 10D so that the output signal S33 from the detector 10C is applied to the control terminal of the switching circuit 10D. The switching circuit 10D selectively passes either of the signals S31 and S32 in accordance with the signal S33. An output terminal of the switching circuit 10D is connected to the input terminal of the low-pass filter 4 so that an output signal S34 from the switching circuit 10D is applied to the low-pass filter 4.

When the signals SL and SR do not contain any vocal or voice components, the binary signal S33 outputted by the detector 10C assumes a low level state so that the switching circuit 10D passes the adder output signal S31 to the low-pass filter 4. Accordingly, in this case, low-frequency components of the adder output signal S31 are selected by the low-pass filter 4 and are then lowered in pitch by the key converter 5 before they are converted by the loudspeaker 3W into a corresponding sound.

When the signals SL and SR contain vocal or voice components, the binary signal S33 outputted by the detector 10C assumes a high level state so that the switching circuit 10D passes the subtractor output signal S32 to the low-pass filter 4. Accordingly, in this case, low-frequency components of the subtractor output signal S32 are selected by the low-pass filter 4 and are then lowered in pitch by the key converter 5 before they are converted by the loudspeaker 3W into a corresponding sound. In general, vocal or voice components are contained in the signals SL and SR at essentially the same levels and phases. Accordingly, these vocal or voice components are cancelled by the subtractor 10B so that the subtractor output signal S32 is essentially free from the vocal or voice components. In this way, when the signals SL and SR contain vocal or voice components, the corresponding vocal or voice components are removed from the signal subjected to key down process in the key converter 5. It should be noted that vocal or voice components would tend to cause distortions in the reproduced sound if they were subjected to the key down process.

The loudspeaker 3W and the amplifier 5 may be omitted from the embodiment of Fig. 18. In this case, the output signal from the key converter 5 is added to each of the signals SL and SR, and the resulting two signals are amplified by the devices 2L and 2R and are then converted by the loudspeakers 3L and 3R into corresponding sounds respectively.

Fig. 19 shows an internal structure of the detector 10C. As shown in Fig. 19, the detector 10C includes an adder 31. The first channel signal SL is applied to a first input terminal of the adder 31. The second channel signal SR is applied to a second input terminal of the adder 31. The two channel signals SL and SR are added by the device 31 to form a signal S35. An output terminal of the adder 31 is connected

to an input terminal of a band-pass filter (BPF) 32 so that the output signal S35 from the adder 31 is applied to the band-pass filter 32. The band-pass filter 32 selects fundamental vocal frequency components from the signal S35 and thereby derives the vocal frequency signal S36 from the signal S35. Specifically, the band-pass filter 32 selects components having frequencies in the range of approximately 90-800 Hz. An output terminal of the band-pass filter 32 is connected to an input terminal of an integrator 33 so that the vocal frequency signal S36 is applied to the integrator 33. This device 33 integrates the vocal frequency signal S36 at a large time constant and thereby derives an integrated signal S37 from the vocal frequency signal S36. When the signals SL and SR contain vocal components, the voltage of the output signal S37 from the integrator 33 exceeds a certain level. When the signals SL and SR do not contain any vocal components, the voltage of the output signal S37 from the integrator 33 is essentially zero. An output terminal of the integrator 33 is connected to a first input terminal of a comparator 35 so that the output signal S37 from the integrator 33 is applied to the first input terminal of the comparator 35. A voltage setting circuit 34 generates a reference signal S38 having a preset constant voltage. An output terminal of the voltage setting circuit 34 is connected to a second input terminal of the comparator 35 so that the reference voltage signal S38 is applied to the second input terminal of the comparator 35. When the level of the output signal S37 from the integrator 33 exceeds the reference level S38, the comparator 35 outputs a high level signal S33. When the level of the output signal S37 from the integrator 33 does not exceed the reference level S38, the comparator 35 outputs a low level signal S33. An output terminal of the comparator 35 is connected to the control terminal of the switching circuit 10D (see Fig. 18) so that the output signal S33 from the comparator 35 is applied to the control terminal of the switching circuit 10D. In this way, when the signals SL and SR contain vocal components, the output signal S33 from the detector 10C assumes a high level state. When the signals SL and SR do not contain any vocal components, the output signal S33 from the detector 10C assumes a low level state.

## Claims

### 1. A low-pitched sound creator comprising:

(a) means for outputting an analog sound signal;

(b) a low-pass filter selecting low-frequency components from the analog sound signal and outputting a low-pitched sound signal representing the selected low-frequency components; and

(c) means for lowering a key of the low-pitched sound signal and thereby deriving a very-low-pitched sound signal from the low-pitched sound signal.

### 2. The sound creator of claim 1 further

comprising means for adding the very-low-pitched sound signal and the analog sound signal to form a processed sound signal, and means for converting the processed sound signal into a corresponding sound.

3. The sound creator of claim 1 further comprising means for converting the analog sound signal into a corresponding sound, and means for converting the very-low-pitched sound signal into a corresponding sound.

4. The sound creator of claim 1 wherein the analog sound signal comprises two channel signals.

5. The sound creator of claim 4 further comprising means for deriving a subtraction between the two channel signals.

6. The sound creator of claim 1 further comprising means for adding the low-pitched sound signal and the very-low-pitched sound signal to form a processed low-pitched sound signal.

7. The sound creator of claim 4 further comprising means for adding the two channel signals to form a mixed signal, a second low-pass filter selecting low-frequency components from the mixed signal and thereby deriving a second low-pitched sound signal representing the selected low-frequency components, and means for adding the second low-pitched sound signal and the very-low-pitched sound signal to form a processed low-pitched sound signal.

8. The sound creator of claim 4 further comprising means for deriving a subtraction between the two channel signals and generating a subtraction signal indicative thereof, means for adding the two channel signals to form a mixed signal, first and second sub low-pass filters included in the low-pass filter, the first sub low-pass filter selecting low-frequency components from the subtraction signal and thereby deriving a first sub low-pitched sound signal representing the selected low-frequency components of the subtraction signal, the second sub low-pass filter selecting low-frequency components from the mixed signal and thereby deriving a second sub low-pitched sound signal representing the selected low-frequency components of the mixed signal, the key-lowering means being operative to lower a key of the first sub low-pitched sound signal to form the very-low-pitched sound signal, means for converting the very-low-pitched sound signal into a corresponding sound, means for detecting an envelope of the second sub low-pitched sound signal, and means for selectively enabling and interrupting the conversion of the very-low-pitched sound signal into the corresponding sound in accordance with whether or not a level of the envelope exceeds a reference level.

9. The sound creator of claim 8 further comprising means for adding the first sub low-pitched sound signal and the very-low-pitched sound signal to form a processed

low-pitched sound signal.

10. The sound creator of claim 8 wherein the enabling/interrupting means includes a switching circuit selectively allowing and inhibiting transmission of the very-low-pitched sound signal to the converting means, and further comprising a third low-pass filter selecting low-frequency components from the mixed signal and thereby deriving a third low-pitched sound signal representing the selected low-frequency components of the mixed signal, and means for adding the third low-pitched sound signal to a signal outputted from the switching circuit to the converting means.

11. The sound creator of claim 4 further comprising means for deriving a subtraction between the two channel signals and generating a subtraction signal indicative thereof, means for adding the two channel signals to form a mixed signal, means for detecting whether or not the two channel signals contain voice components, and means for selectively passing either of the subtraction signal and the mixed signal to the low-pass filter in accordance with whether or not the two channel signals contain voice components.

12. The sound creator of claim 11 wherein the detecting means comprises means for adding the two channel signals to form a second mixed signal, a band-pass filter selecting components in a preset frequency band from the second mixed signal and generating a band-pass signal representing the selected components, the preset frequency band corresponding to a fundamental frequency range of voice components, means for integrating the band-pass signal and thereby deriving an integral signal from the band-pass signal, and means for comparing the integral signal and a reference level.

13. The sound creator of claim 1 wherein the low-pass filter comprises first and second sub low-pass filters having different cut-off frequencies and deriving first and second sub low-pitched sound signals from the analog sound signal respectively, and further comprising means for selectively passing either of the first and second sub low-pitched sound signals to the key-lowering means.

14. The sound creator of claim 13 further comprising means for adding the analog sound signal and the very-low-pitched sound signal to form a processed low-pitched sound signal.

15. The sound creator of claim 14 further comprising means for selectively allowing and inhibiting the addition of the analog sound signal and the very-low-pitched sound signal.

16. A low-pitched sound creator comprising:

(a) means for outputting two channel sound signals;

(b) means for deriving a subtraction between the two channel signals and thereby generating a subtraction signal indicative thereof;

(c) means for adding the two channel

signals to form a mixed signal;

(d) a first low-pass filter selecting low-frequency components from the subtraction signal and thereby generating a first low-pitched sound signal representing the selected low-frequency components of the subtraction signal;

(e) a second low-pass filter selecting low-frequency components from the mixed signal and thereby generating a second low-pitched sound signal representing the selected low-frequency components of the mixed signal;

(f) means for lowering a key of the first low-pitched sound signal and thereby deriving a very-low-pitched sound signal from the first low-pitched sound signal;

(g) means for detecting an envelope of the second low-pitched sound signal; and

(h) means for selectively passing and cutting off the very-low-pitched sound signal in accordance with the detected envelope.

17. A low-pitched sound creator comprising:

(a) means for outputting an analog sound signal;

(b) first and second low-pass filters having different cut-off frequencies and deriving first and second low-pitched sound signals from the analog sound signal respectively;

(c) means for selecting arbitrary one of the first and second low-pitched sound signals; and

(d) means for halving a key of the selected low-pitched sound signal and thereby deriving a key-halved signal from the selected low-pitched sound signal.

18. A low-pitched sound creator comprising:

(a) means for outputting two channel sound signals;

(b) means for deriving a subtraction between the two channel signals and thereby generating a subtraction signal indicative thereof;

(c) means for adding the two channel signals to form a mixed signal;

(d) means for detecting whether or not the two channel signals contain voice components;

(e) means for selecting arbitrary one of the subtraction signal and the mixed signal in accordance with whether or not the two channel signals contain voice components and thereby generating a selected signal representing the selected one of the subtraction signal and the mixed signal;

(f) a low-pass filter selecting low-frequency components from the selected signal and thereby generating a low-pitched sound signal representing the selected low-frequency components; and

(g) means for halving a key of the low-pitched sound signal and thereby deriving a very-low-pitched sound signal

from the low-pitched sound signal.

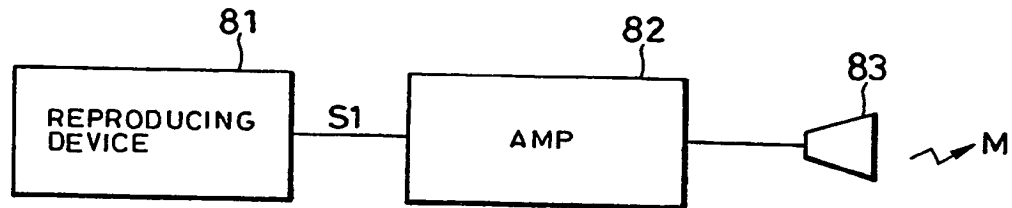
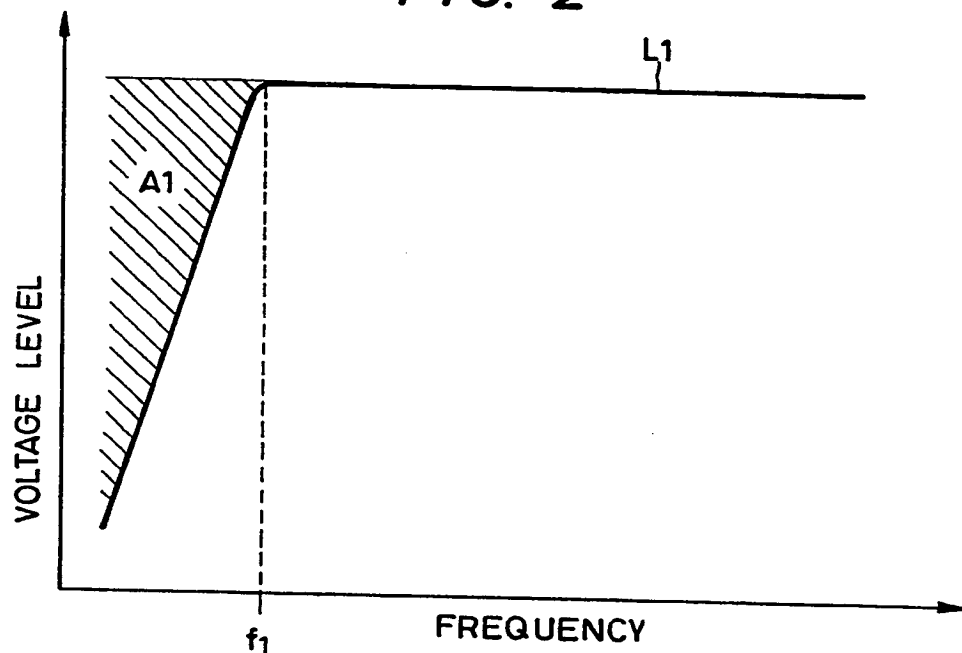
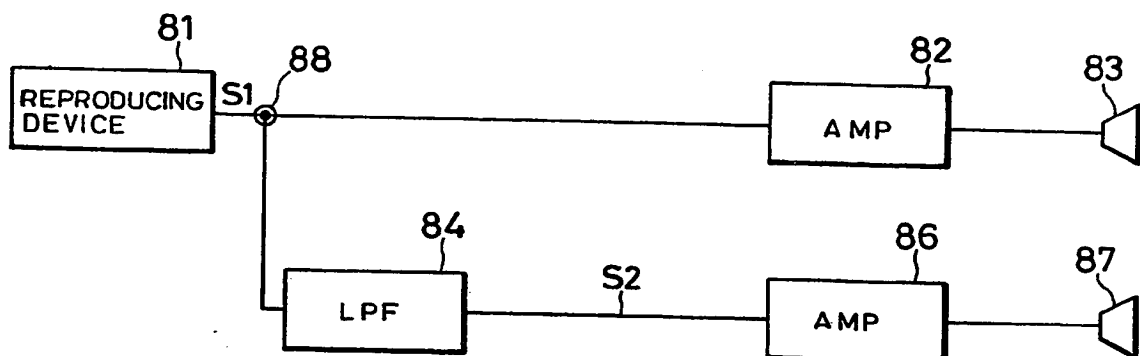
19. A method of creating a low-pitched sound comprising the steps of:

(a) selecting low-frequency components from a sound signal;

(b) lowering a key of the selected low-frequency components; and

(c) converting the key-lowered components into a corresponding sound.

20. The method of claim 19 further comprising converting the sound signal into a corresponding sound.

*FIG. 1 PRIOR ART**FIG. 2**FIG. 3 PRIOR ART*

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FIG. 4

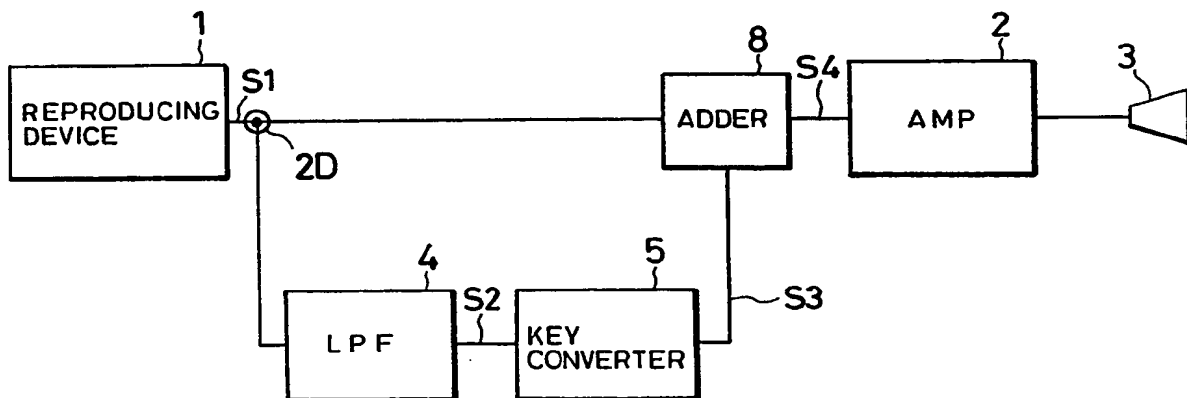


FIG. 5

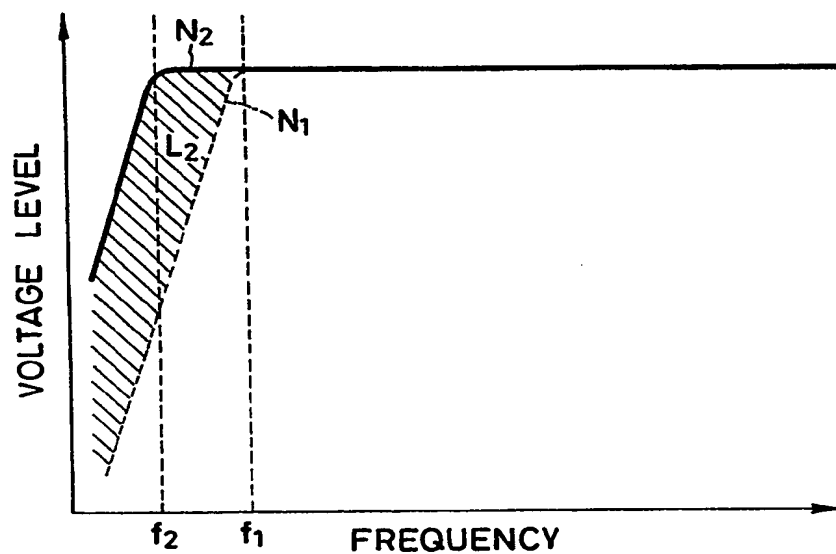
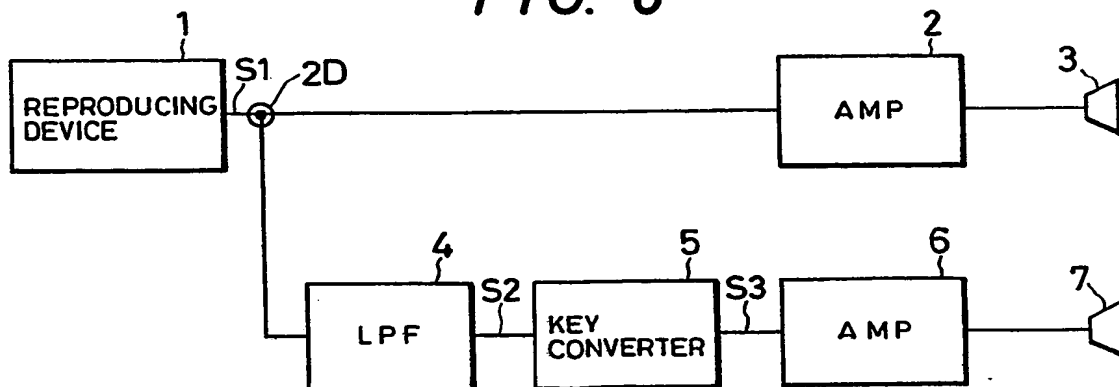


FIG. 8



**FIG. 6**

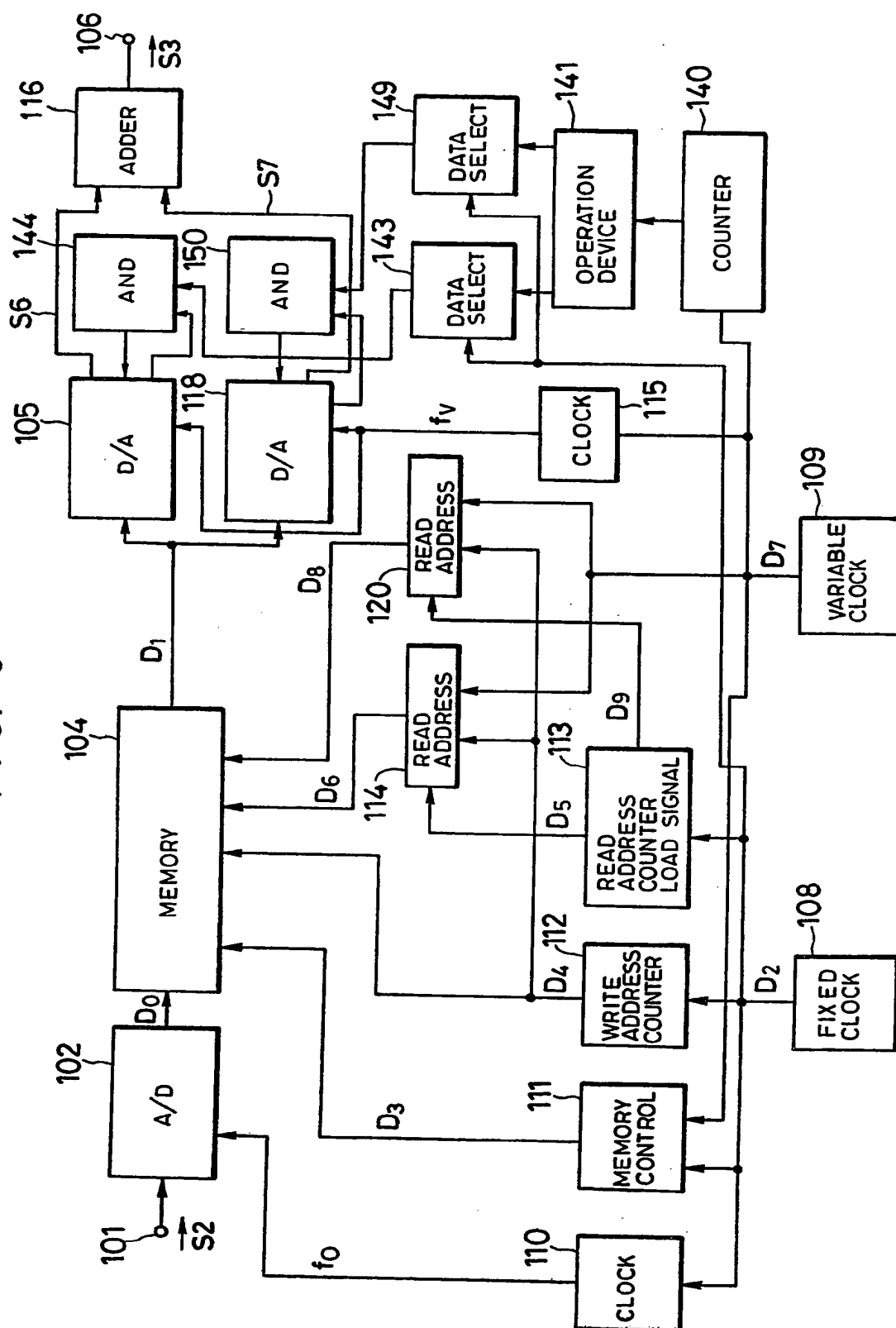




FIG. 7

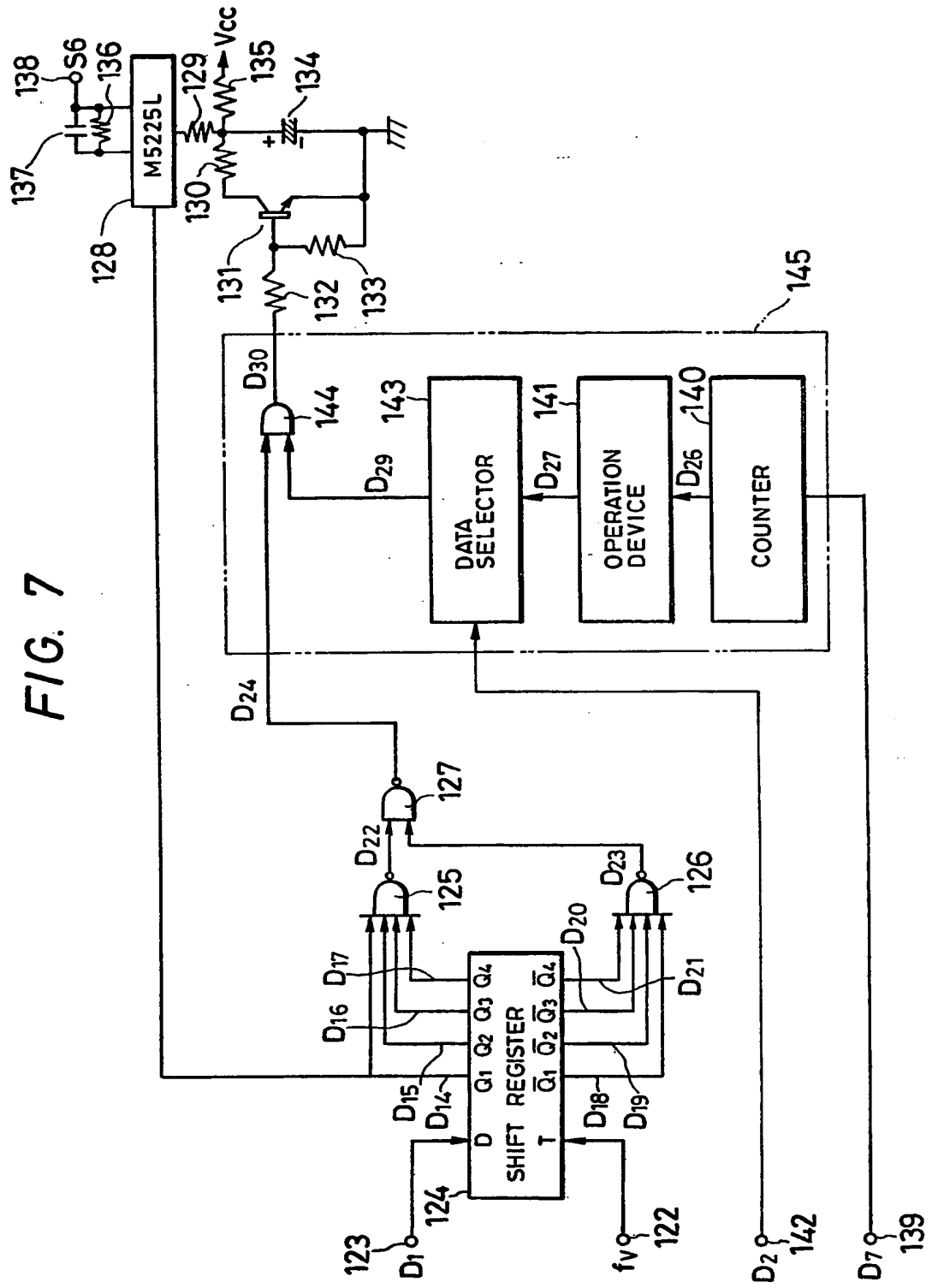


FIG. 9

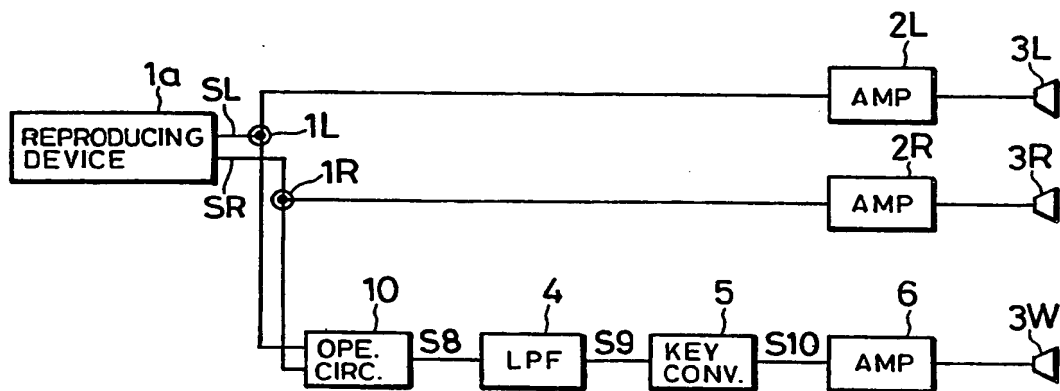


FIG. 10

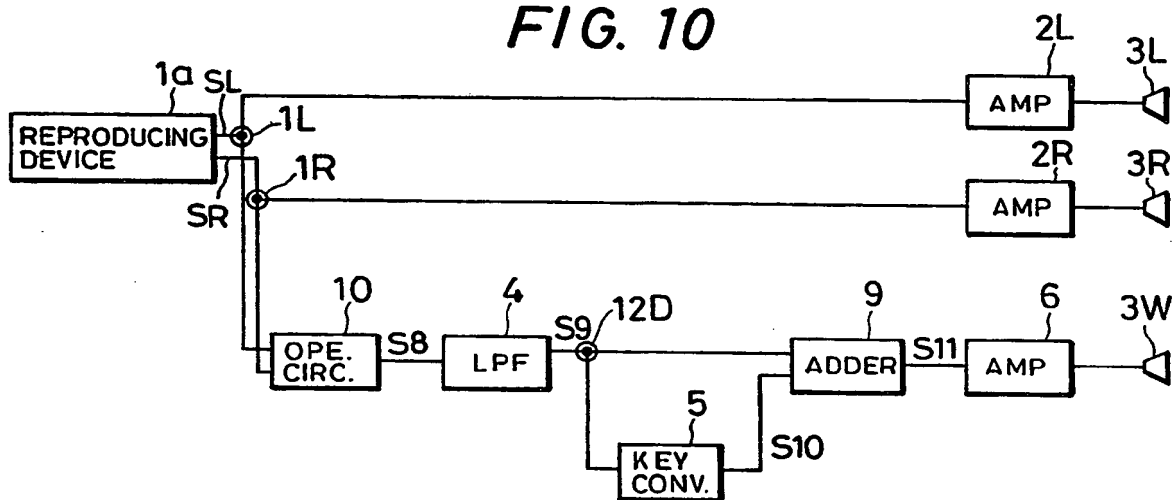


FIG. 11

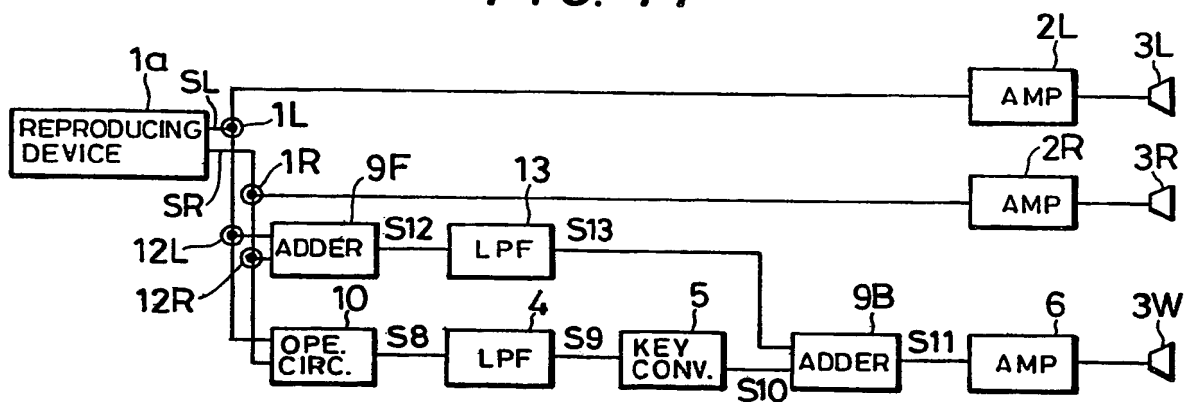


FIG. 12

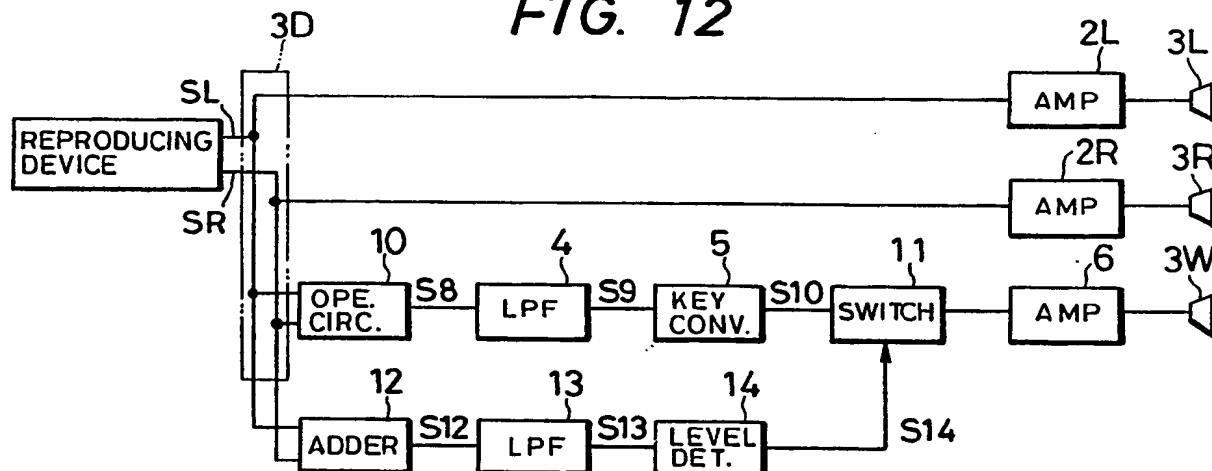


FIG. 13

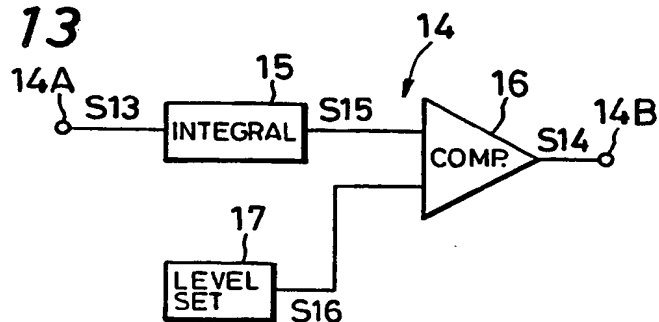


FIG. 14

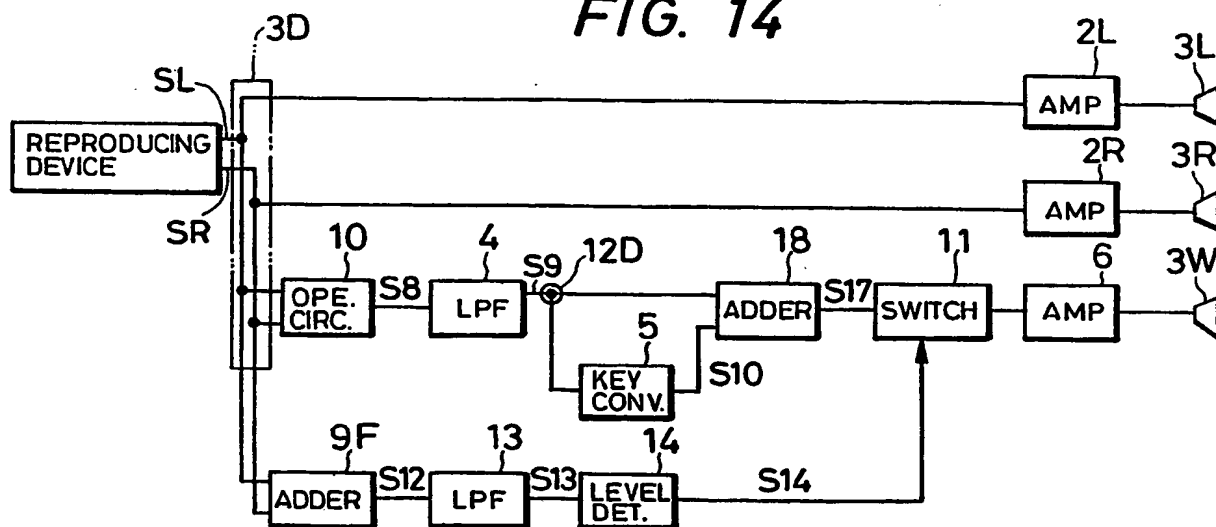


FIG. 15

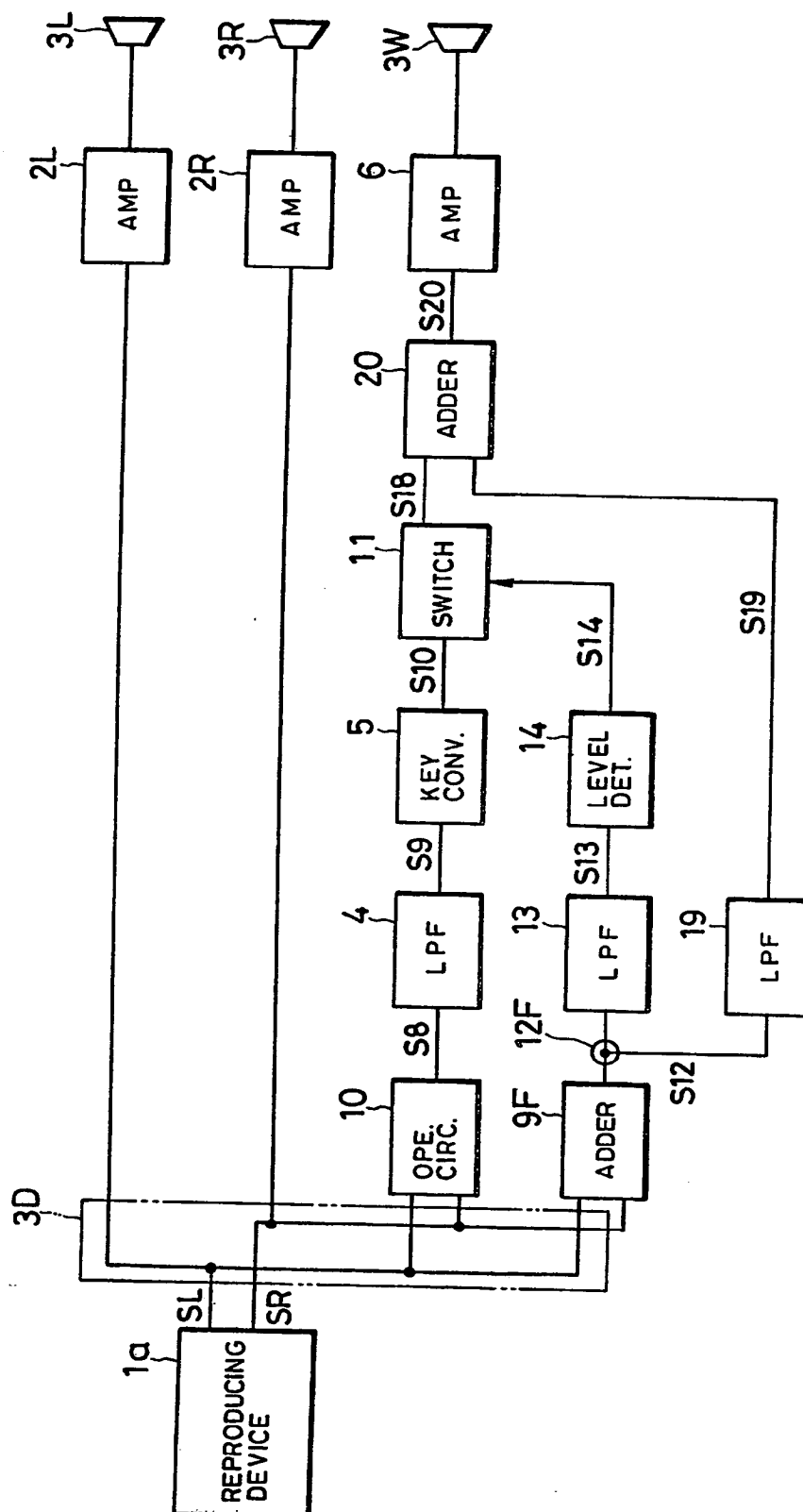


FIG. 16

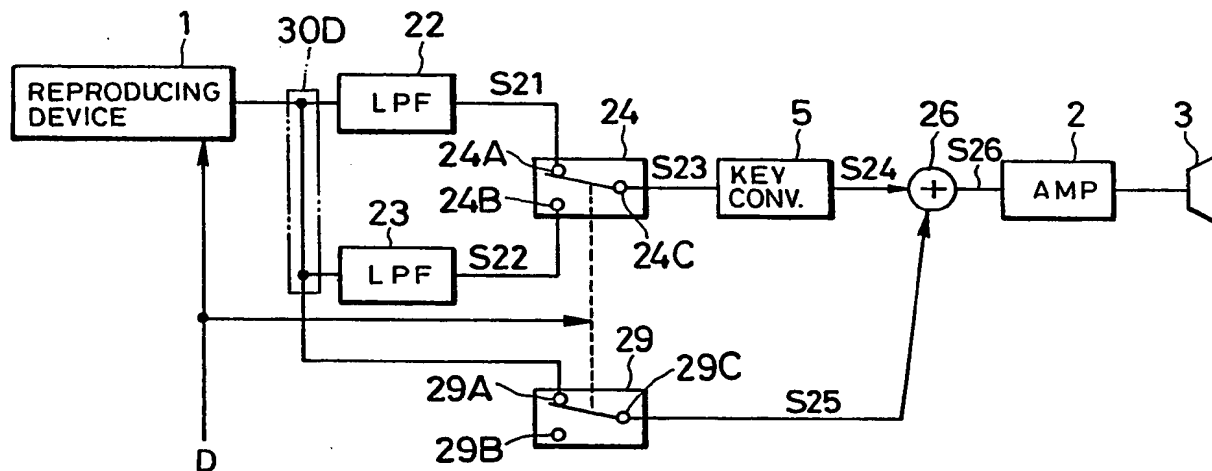
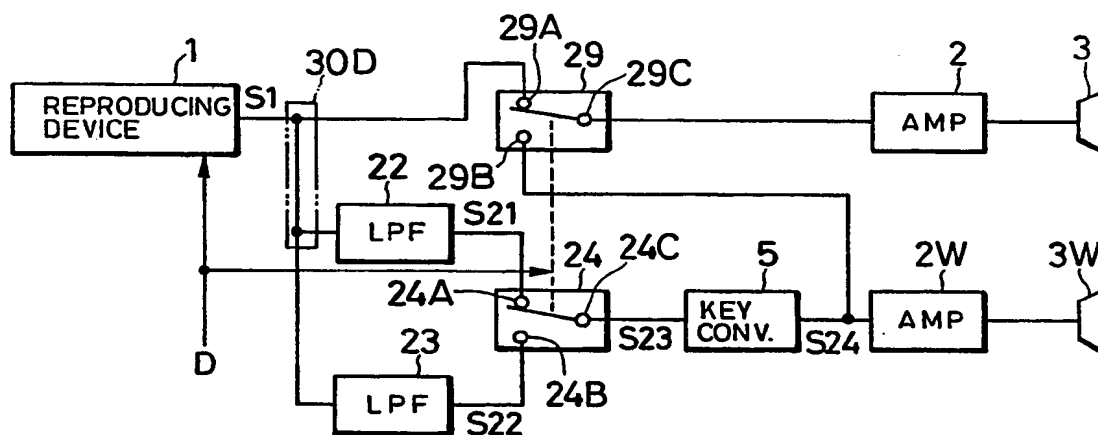


FIG. 17



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FIG. 18

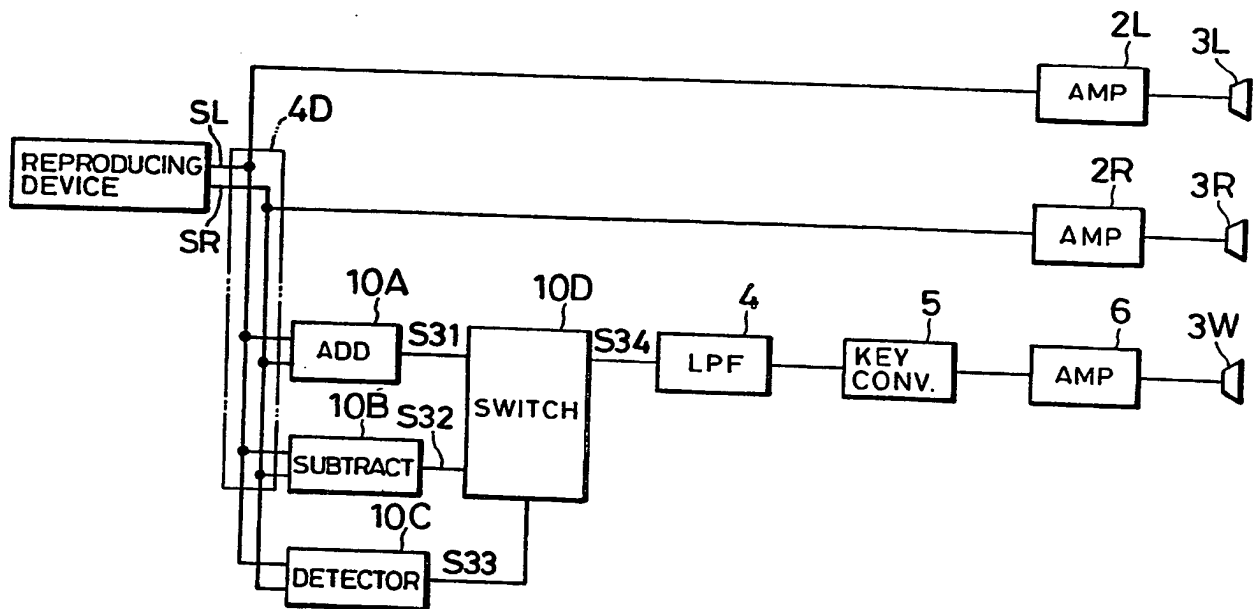
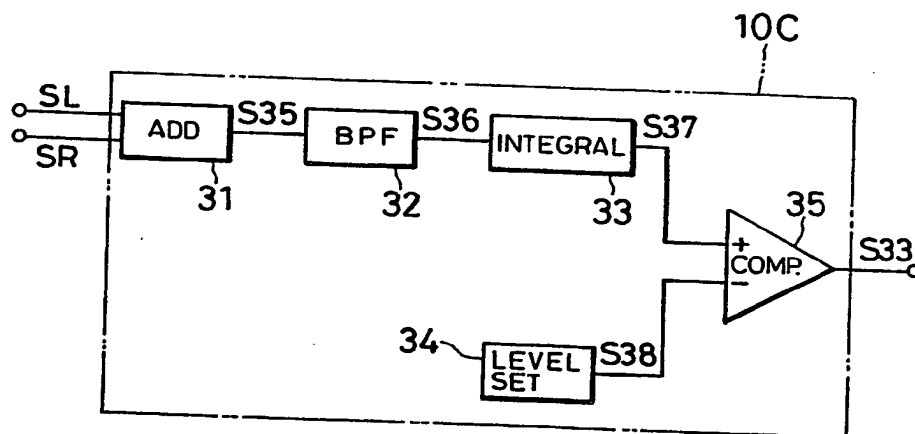


FIG. 19



(19)



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**A3**

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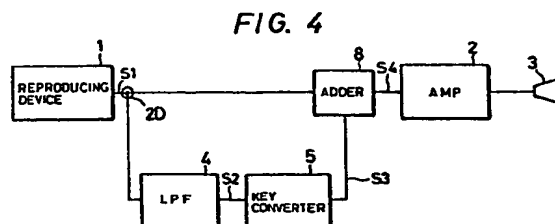
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- (71) Applicant: Matsushita Electric Industrial Co., Ltd.  
1006, Oaza Kadoma  
Kadoma-shi Osaka-fu, 571(JP)
- (72) Inventor: Watanabe, Koji  
Kourigaoka Gaaden Haitsu 504S12-4  
Kourigaoka 9-chome Hirakata-shi Osaka(JP)  
Inventor: Hayashi, Katsuhiko Mingle AP  
Akane Ichibankan 2B  
3-32, Kikawa Nishi 4-chome  
Yodogawa-ku Osaka-shi Osaka(JP)  
Inventor: Minakuchi, Nobuaki  
35-1110, 5-ban Kasuga 1-chome  
Suita-shi Osaka(JP)  
Inventor: Misaki, Masayuki  
76, Nishinokyo Shokushi-cho Nakagyo-ku  
Kyoto(JP)  
Inventor: Terai, Kenichi  
3-1306, 1-ban, Shigino Nishi 2-chome Joto-ku  
Osaka-shi Osaka(JP)  
Inventor: Nakama, Yasutoshi  
1658-499, Kita Tahara-cho  
Ikoma-shi Nara-ken(JP)
- (74) Representative: Senior, Alan Murray et al  
J.A. KEMP & CO 14 South Square Gray's Inn  
London WC1R 5EU(GB)

(54) Low-pitched sound creator.

EP 0 240 286 A3

(57) Low-frequency components (S2) are selected from the outputted analog sound signal (S1) so that a low-pitched sound signal is derived from the analog sound signal. A key of the low-pitched sound signal is lowered so that a very-low-pitched sound signal (S3) is derived from the low-pitched sound signal (S2). The analog sound signal (S1) and the very-low-pitched sound signal (S3) may be converted into corresponding sounds respectively (S4).





European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number

EP 87 30 2735

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X  A	US-A-4 051 331 (W. STRONG) * Figure 2; column 4, line 17 - column 7, line 16 *	1-3,6,7 ,17,19, 20 4,5,8- 15,16, 18	H 03 G 5/16 G 11 B 5/035 H 04 R 25/00
X  A	DE-A-2 908 999 (SIEMENS) * Figure; page 12, line 1 - page 14, line 6 *	1-3,6,7 ,17,19, 20 4,5,8- 15,16, 18	
X	DE-B-1 261 169 (CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE) * Whole document *	1-3	
X	DE-A-2 613 513 (A. KREMER) * Whole document *	1-3	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			H 03 G G 11 B H 04 R
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 08-07-1988	Examiner DECONINCK E.F.V.
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document  T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons  & : member of the same patent family, corresponding document			

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